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(71) Applicant(s)
Luk Getriebe-Systeme GmbH

(Incorporated in the Federal Republic of Germany)

Industriestraße 3, 77815 Bühl, Baden, Federal Republic of Germany

(72) Inventor(s)
Burkard Kremmling
Michael Salecker
Martin Zimmermann

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(74) Agent and/or Address for Service
Dummett Copp
25 The Square, Martlesham Heath, IPSWICH, Suffolk, IP5 3SL, United Kingdom

(54) **An automatic clutch system with temperature dependent volume compensation means**

(57) A vehicle automatic clutch control system comprises a brake fluid circuit 5 having a transducer cylinder 1, connected to a receiver cylinder 2 by a pipe 3, and a supply container 4. A snifting bore 25 is connected via pipe 24 to the container 4 (also see figs 2 and 3) so that as the brake fluid in pipe 3 expands, due to temperature rises, the excess volume is compensated by diverting it through bore 25 and pipe 24 to container 4. Without this volume compensation, accurate engagement point detection would not be possible since expansion of the brake fluid column would falsify the relationship between the actual and measured clutch positions. Volume compensation is carried out by closing the clutch cyclically for a duration of, for example, one second and is interrupted when, for example, neutral is selected or a gear is engaged. Other embodiments include a control unit which engages the clutch, according to various algorithms etc, to cause the vehicle to crawl and software/hardware emergency circuits. In all other aspects the clutch operates, by way of hydraulic circuit, in a typical manner with regard to gear changing, starting and stopping etc.

Fig.1

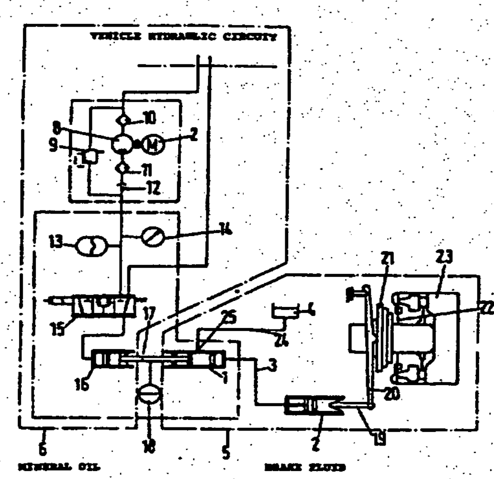

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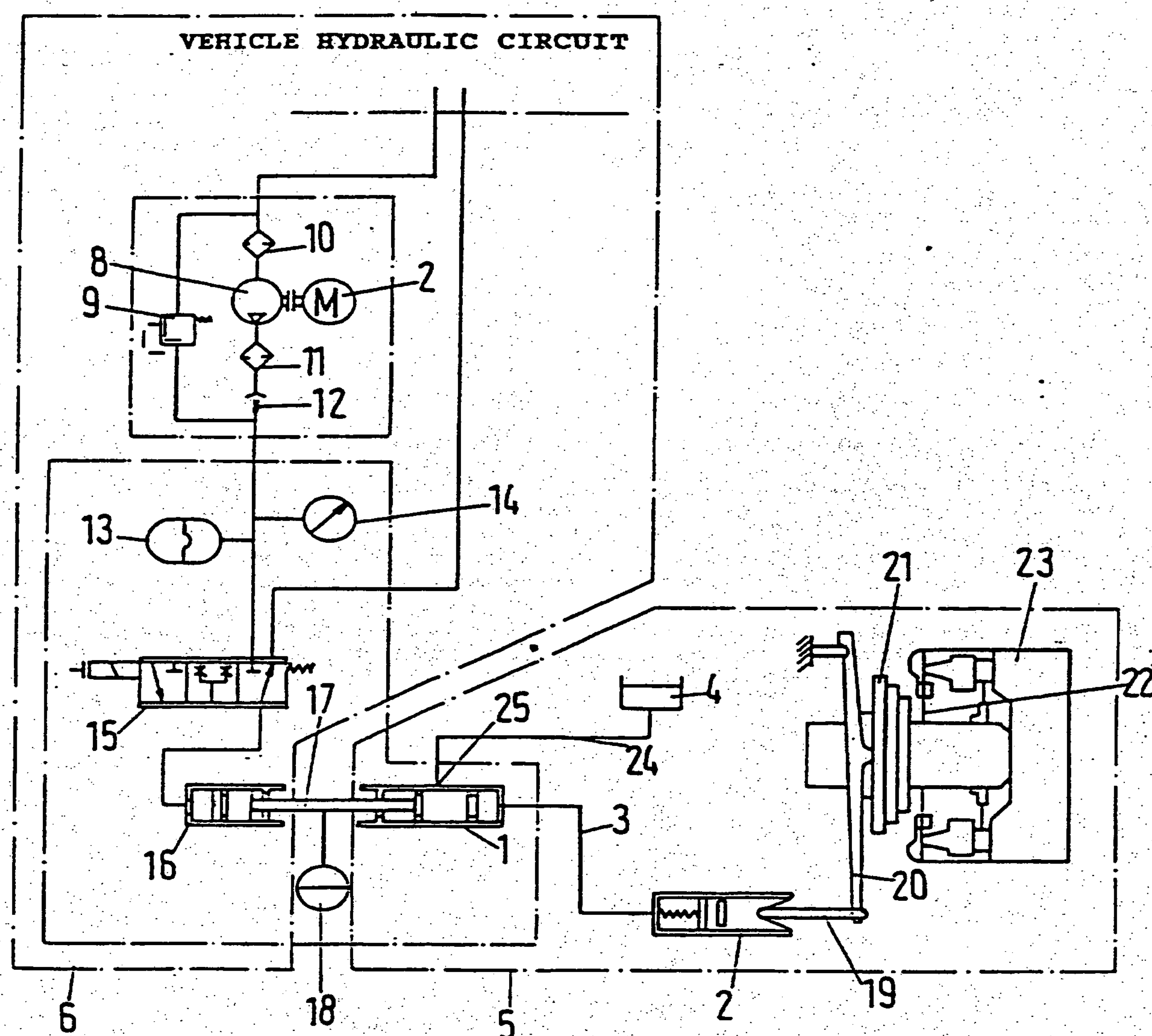
Fig.1


VEHICLE HYDRAULIC CIRCUIT
10
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25
24
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17
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1
3
20
18
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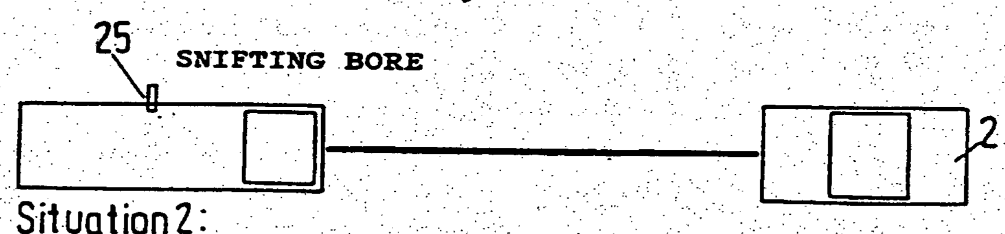
19
MINERAL OIL
BRAKE FLUID

Fig.2


25
SNIFTING BORE
2
Situation 1:
1

Fig.3


25
SNIFTING BORE
2
Situation 2:

Motor vehicle

The invention relates to motor vehicles which have an automatic clutch provided in the torque path between the combustion engine and a stepped gear change, as well as at least one switching and control unit or regulator for same. These have become known by the term "Electronic Clutch Management" or "ECM" in short, eg in connection with DE-OS 40 11 850.

The object of the present invention is to increase the safety of vehicles equipped with such systems by making the driver aware through the invention not to get out of the vehicle leaving the gear engaged in certain operating conditions, such as when the vehicle is stationary with the engine running and gear engaged, such as for example when stopping in front of the garage (in the corresponding operating state the clutch is in the ready position because the accelerator is not operated), because in this case, in the event of a fault in the disengagement system, eg a drop in pressure in the hydraulic system of the automatic clutch the clutch would close. Furthermore the comfort of the vehicle is to be increased, by, for example when changing gear, being able to transfer the engine torque more sensitively to the drive wheels, and furthermore starting off on icy roads should become much easier. The object of the invention is also to make such systems and thus vehicles equipped with same more economical, to make the control regulation more finely sensitive and faster-acting and in the event of faults to make these known to the driver and/or the workshop by storing such faults in for example a fault memory store, preferably a non-volatile fault memory store. Furthermore the electronic hardware used should be simplified and capable of universal use, the number of senders and/or receivers should be kept as low as possible

and furthermore the smallest possible alterations need have to be made when fitting an ECM in vehicles.

According to the invention there is provided a motor vehicle with an internal combustion engine and a gearbox and an automatic clutch mounted in the torque flow and at least one control device for the clutch, as well as with a hydraulic system with sender cylinder, receiver cylinder and a hydraulic line between sender and receiver cylinders, a hydraulic fluid and a device for volume compensation and a snifting bore, characterised in that the clutch is closed controlled at least from time to time and a volume compensation of the hydraulic fluid is carried out.

At least the part of the problem relative to improved safety, increased comfort and better driving conditions is solved in that through the automated clutch with the gear engaged and the engine running as well as with the vehicle stationary or practically stationary and the fuel supply measuring member (ie accelerator) not operated, the clutch is closed until a lower torque is transferred which causes the vehicle to crawl along.

This crawling thus makes the driver give up any idea of leaving the vehicle after coming to a standstill with the engine running and gear engaged, simply because the vehicle begins to crawl along immediately after a stoppage caused by the brake, thus foot or hand brake. This crawling also ensures however a higher comfort when parking, changing gear etc and when starting up on icy roads because a fine sensitive start is possible.

It is furthermore of advantage if on operating the brake by a foot or hand brake during crawling the clutch is activated in the opening direction and thus the transferrable moment

is at least reduced which can take place through a continuous or abrupt opening, eg into the ready position.

Furthermore it can be advantageous if with the brake activated, the vehicle stationary or practically stationary and the gear engaged whilst the accelerator is not activated the clutch is held in a position off-set from the position causing the crawling, thus in a ready, waiting or off-set position.

It can be particularly advantageous if with the brake not activated and the accelerator not activated during the crawling process the clutch is continuously operated in the direction of closing, thus in the idling operation a continuous speed increase takes place in order not to overheat the clutch through the continuous crawling connected with relatively large slip.

The waiting or off-set position can be recorded per se in a memory, such as an electronic memory and removed from same or sent on to a corresponding receiver when required. The waiting or off-set position can however also be formed in that the so-called engagement point of the clutch, thus where the clutch just starts to transfer torque, is detected and automatically a slight value off-set from the engagement point (the off-set) is added and the value thus obtained can be recorded in the electronic hardware, such as eg a computer, and can then be removed from this.

It has furthermore proved advantageous if after starting the engine, with the vehicle stationary or practically stationary, the accelerator not activated, the brake not activated and in dependence on engaging a starting gear the clutch is operated from a position transferring no starting moment (such as eg the ready-off-set or waiting position)

permanently in the closing direction so that the vehicle starts to crawl along and wherein the slip present in the clutch can be permanently reduced, thus the crawl becomes faster and faster. Also here it is advantageous if on operating the brake the closing process of the clutch is at least interrupted or the clutch is further opened, until for example into the ready position.

It is particularly expedient if after switching off the engine the clutch is automatically closed wherein it can be particularly advantageous if the clutch is also closed when the gear is engaged in order to produce a reliable gearbox lock. It can then be expedient if the closing of the clutch which takes place when the gear is engaged is produced slightly delayed in time after switching off the engine since the engine can still run on after turning off the ignition.

It is furthermore advantageous if after starting the engine which can preferably take place only when the gear is in neutral, the clutch is guided into a position extending over the engagement point, such as a completely opened position, but with the introduction of engaging a starting gear the clutch is guided into the ready position which can take place for example in dependence on detecting a certain gear through gear recognition.

It can then be particularly advantageous if even when the accelerator is not activated and the gear is engaged the clutch is operated from the position transferring no starting torque, thus more particularly the ready, off-set or waiting position, permanently in the closing direction, thus the vehicle starts to crawl wherein the clutch can be closed regulated or controlled. Closing from the ready position into the engagement position and/or from the

engagement position into the further or completely closed position can take place controlled according to a time dependent torque curve or however regulated in dependence on the slip of the ideal torque detected between the engine and gearbox wherein each larger value has preference. It is also possible and indeed of advantage if the closing of the clutch eg from the ready position into the engagement position and/or from the engagement position into the engaged position takes place without direct detection of the gearbox speed whereby instead of the gearbox input speed a value corresponding to this input speed can be calculated from the vehicle speed, eg from a driving speed signal which is taken from eg a control device such as the DME (digital motor electronics) and wherein by taking into account the engaged gear and the corresponding gear translation the speed occurring in the force transmission path behind the clutch, thus the gearbox input speed, can be calculated. This can be achieved in a particularly simple way through the electronics hardware, the travelling speed signal is in any case present and can be calculated back by means of the gear translation recorded in the electronic device. The engaged gear is produced from the so-called gear detection. With a device of this kind it is possible to dispense with a sensor for detecting the gearbox input speed and when using an ECM system of this kind there is no need to make any alterations on the switch gear.

The engagement position already mentioned several times corresponds at least approximately to that position of the clutch where the vehicle also starts to crawl. It is thereby advantageous if after starting the combustion engine the clutch can preferably be completely opened.

Furthermore it can be advantageous if for measuring the path of the clutch position an element of the disengagement

system is used which is remote from the clutch operating means, such as the disengagement bearing, wherein in the case of a fluid-operated disengagement system, such as eg a hydraulic system, the path measurement is carried out indirectly or directly through the transducer cylinder. To this end a swivel lever can be operated through the ram of the hydraulic cylinder, this lever having on its axis a rotary potentiometer. This type of measurement is particularly advantageous because no changes have to be made on the gearbox bell housing. Since however the hydraulic fluid - the hydraulic clutch operating system can be attached to the brake fluid circuit - cannot avoid a temperature-dependent volume expansion, the relationship of the actual clutch position on the receiver cylinder and the measured clutch position on the transducer cylinder can be falsified, at least until the next volume compensation takes place through the snifting bore to the supply container of the hydraulic fluid.

In order to compensate such errors or to make sure they do not arise, it is particularly advantageous if more than one method of determining the engagement point is used.

One method of determining the engagement point takes place with the gear in neutral position when the vehicle is stationary or practically stationary wherein it can be particularly expedient if this engagement point detection (stationary engagement point) is carried out periodically. If required it is possible to carry out in addition to or in place of the aforesaid engagement point detection a stationary engagement point detection even when the gear is engaged, the foot brake is operated and the vehicle is stationary or practically stationary. It is thereby particularly advantageous if this engagement point detection is carried out periodically. The corresponding values

detected through the potentiometer can be supplied to a memory - as will be described in detail later on.

A further method of detecting the engagement point exists according to the invention in the push and/or pull operation (push or pull engagement point).

The push engagement point can thereby take place in the "accelerator position zero" at a setting of the clutch - with closing of same seen in this direction - after understepping the ready position and on determining the minimum engine speed, which can be achieved by detecting a rise in the speed after a drop in same, thus on ascertaining the first occurring positive gradient, thus a state for which the torque of the clutch actually transferrable equals the engine thrust torque, this value being associated through the engine characteristic field recorded in the electronic hardware with a certain thrust or braking torque of the engine, and the corresponding distance to the potential, thus next, engagement point being associated with this value through the clutch characteristic line likewise recorded in the hardware electronics.

The engagement point detection in the pull operation can be carried out for example by integrating the speed difference between the engine and gearbox, thus the slip over the time, so that a certain surface is produced, and on exceeding this integrated surface the engagement point is corrected by a certain value in the closing direction, and on understepping this integrated surface the engagement point is corrected in the opening direction by a certain value.

The additional engagement points detected alongside the stationary engagement point can also be supplied to a memory wherein it is expedient if the stationary engagement point

can be stored in a volatile memory and the push or pull engagement point in a non-volatile memory. Depending upon the type of use it can be advantageous if only the push engagement point is detected or only the pull engagement point. However in many cases it can be advantageous if both the push and the pull engagement points are detected and stored.

For storing the detected ready positions (or engagement point which is then corrected as already described by a certain value) it is possible to provide a volatile central engagement point memory which receives the values transferred from the other memories, namely the stationary engagement point memory and the push and/or pull engagement point memories. The values of the stationary engagement point memory can thereby each be transferred from the central engagement point memory after a or with each periodically occurring detection and eg in dependence on reaching the ready position of the clutch.

The values of the "push and/or pull" engagement point are transferred immediately after detection and in dependence on an at least approximately full closing of the clutch into the central engagement point memory and are kept ready for regulation or are passed on to the regulator.

As already mentioned above, the push and/or pull engagement point can be received after an at least approximately complete closing of the clutch (when the vehicle is to be moved eg in the slip operation) or in dependence on the complete closing of the clutch. The acceptance of the push and/or pull engagement point in the central engagement point memory can however also be carried out in dependence on the clutch being closed so far where the torque transferrable by the clutch is higher than the engine torque existing at this

point in time.

The adoption of the push and/or pull engagement point can however also be undertaken in dependence on an at least approximately complete opening of the clutch. In many cases it can be expedient if the adoption is carried out on reaching the ready position.

The adoption of the push and/or pull engagement points in the central (volatile) engagement point memory can however also be carried out in dependence on reaching that position of the transducer cylinder where a volume balance is made with the supply container through the snifting bore, which is thus generally the case when the clutch is engaged.

Storing the relative last engagement point detection in the central volatile engagement point memory can be carried out in dependence on the clutch still being free. Whilst this value is cancelled as soon as the clutch is temporarily closed, eg for a second, snifting occurs and a volume compensation in the hydraulic clutch disengagement system and the engagement point detected with push and/or pull is stored in the (non-volatile or adaptive memory) push and/or pull engagement point memory and is passed onto the volatile central engagement point memory. After switching off the engine the engagement point memory state and the central engagement point memory are cancelled whilst the values stored in the non-volatile engagement point memory for the push and/or pull operation remain recorded or stored and when next starting up are fed into the central volatile engagement point memory and used for controlling or adjusting the clutch to the engagement point thereof.

Closing the clutch from a fully or an at least approximately fully opened position into the ready position can be carried

out according to a controlled function. Closing the clutch when starting from the ready position can be carried out in dependence on the ideal starting speed which is dependent on the load lever position, thus on the accelerator pedal or throttle valve.

Closing the clutch during re-engagement after changing gear from the ready position can be carried out in dependence on an ideal slip. This ideal slip can be regulated on the basis of an actual slip at the beginning of engagement, thus at least one approximately on reaching the ready position over a time slope towards the desired end slip wherein the desired end slip can be nil (if for example there should be no driving with slipping clutch for the purpose of vibration insulation). The torque set at the clutch can thereby be at least the engine torque times a factor of ≥1. The engine torque can thereby be detected from the position of the load lever and the engine speed.

The ideal torque of the clutch detected through the regulator (or regulator algorithm) activated in each operating state (crawling and/or starting up and/or re-engagement) is converted through the clutch characteristic line into an ideal value. The ideal path can thereby be compared in a path control circuit with the actual value of the clutch and from this the ideal current required for the valve control can be determined through a PID regulator.

The invention will now be explained in further detail with reference to the embodiments shown in the drawings.

Figure 1 thereby shows the arrangement of the hydraulic system components with transducer cylinder 1, receiver cylinder 2 with the hydraulic pipe 3 connecting same, and the supply container 4 on one side as the brake fluid

circuit 5 and on the other the hydraulic circuit of the vehicle 6, consisting of the engine 7 with pump 8, pressure restrictor valve 9, filters 10 and 11 and non-return valve 12. This hydraulic circuit also contains a memory 12, a pressure sensor 14, the 4/3-way valve (proportional valve) 15 and the transducer cylinder 16 of the hydraulic circuit of the vehicle. The piston rod 17 of the cylinder 16 is at the same time the input piston rod for the piston cylinder unit 1. The piston rod 17 is used to operate a rotary potentiometer 18 which produces and sends out a signal for the clutch position. The piston rod 19 of the receiver cylinder unit 2 operates the clutch operating lever 20 which in turn operates a disengagement bearing 21 through which the plate spring 22 (shown diagrammatically) of the clutch 23 (likewise shown diagrammatically) is operated.

The pipe 24 connecting the cylinder unit 1 with the supply container 4 opens into the cylinder unit 1 through the snifting bore 25 shown in further detail in Figures 2 and 3.

IMPLEMENTATION IN DETAIL

The torque build up when starting up is determined by three independent calculations. These are the prediction regulator, the disengagement strategy and the crawl regulator. Each of these regulators calculates an ideal torque wherein the maximum torque is adopted as the resulting starting torque.

Flow diagram of the starting regulation

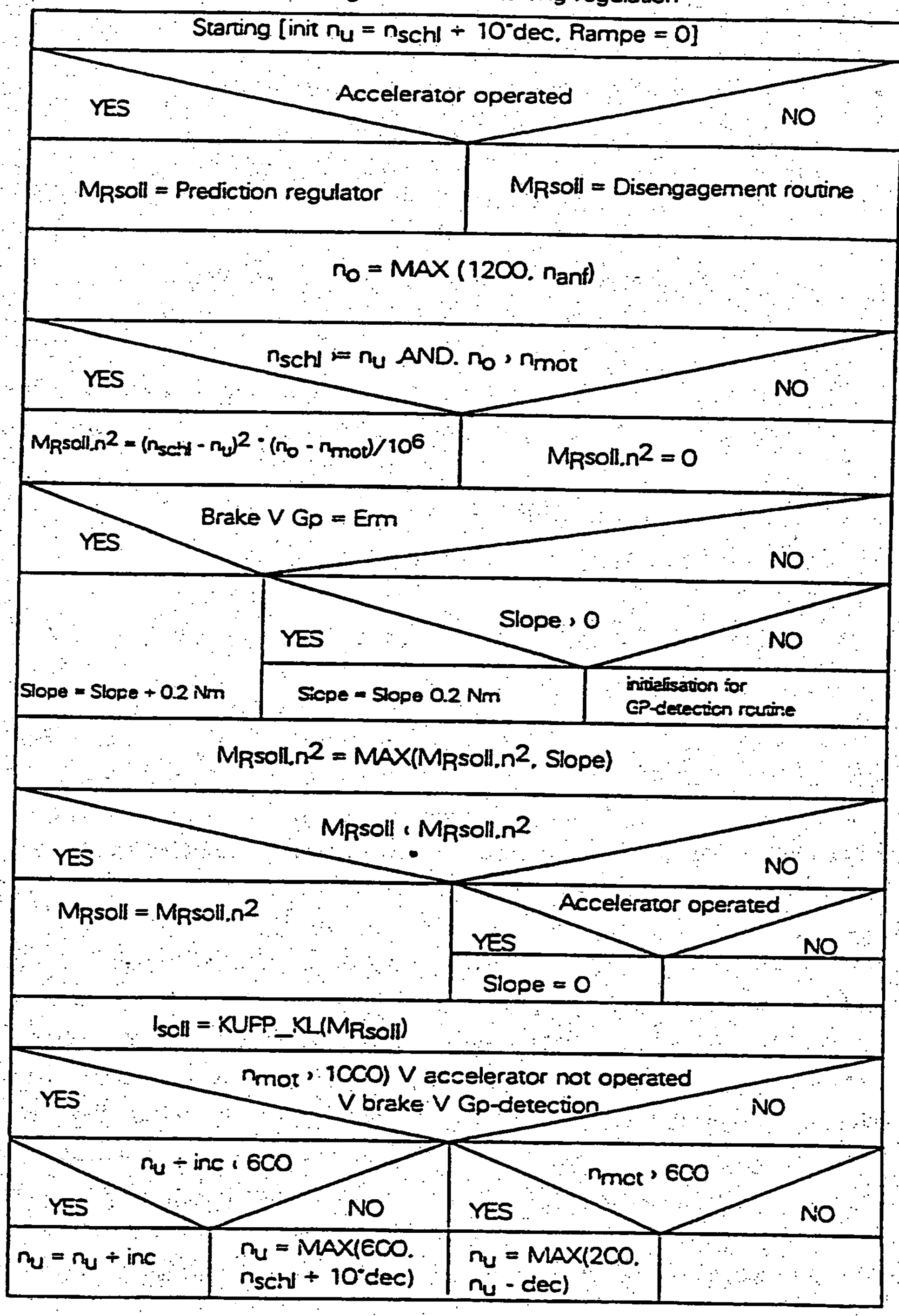


Fig. 1: Structogram of the crawl regulator embedded in "driving" state

Here the following applies:

n_u	lower speed barrier (rpm)
n_o	upper speed barrier (rpm)
n_{anf}	starting up speed (rpm)
n_{mot}	engine speed (rpm)
n_{schl}	filtered slip between engine and gearbox (rpm)
M_{Rsoll}	ideal friction torque (Nm)
M_{Rsoll,n^2}	ideal friction torque of crawl regulator (Nm)
inc=4	increment for change in lower barrier (rpm)
dec=4	decrement for change in lower barrier (rpm)

When first starting off the crawl regulator is initialised as follows:

- lower barrier n_u to ideal slip + offset
- slope to torque = 0

The crawl regulator is comprised of a n^2-regulator which calculates its torque in dependence on the engine value and a value reset to the gearbox speed, and of a time-dependent torque slope with a rise of 20 Nm/s. The maximum torque is adopted as the crawl torque.

The torque of the slope is built up when there is no throttle and no brake operated. If the foot brake is operated or the hand brake tightened then the torque breaks down with the same gradient with which the torque was previously built up. The slope serves to close the clutch in the event of longer crawling in each case when the torque of the n^2-regulator, conditioned through the increasingly reducing slip, passes to nil. The n^2 regulator alone would set a fixed slip which in the event of longer crawling could

lead to an unacceptably high wear on the clutch.

The ideal friction torque of the starting-up regulation with prediction regulator is indirectly dependent on the throttle valve. If the accelerator is pressed down then as a rule the prediction regulator is operated. Otherwise the disengagement routine predetermines the path of the ideal torque. Thus in the event of an interrupted start the disengagement routine is activated in order to break down the torque of the prediction regulator to the crawling torque.

The n^2 regulator has the following algorithm:

$$M_{Rsoll,n^2} = (n_{schl} - n_u)^2 \cdot (n_o - n_{mot}).$$

The upper barrier n_o has the result that the torque breaks down as the engine speed increases, thus when pressing down the accelerator, and on exceeding this barrier is set completely to nil. This means that a torque is immediately built up through the n^2 - regulator which is however exceeded when accelerating after a short time by the prediction regulator and is solely determined by this. A pre-requirement for a "comfortable" adoption through the prediction regulator is a small difference between the gradients of the two ideal torques in the transfer point.

The lower barrier n_u takes care of the torque build-up when crawling, so long as the accelerator is not depressed, and for a torque break-down when the brake is operated. The barrier is initialised when entering the state "starting up" to the actual slip + offset. The additional offset serves for the ideal clutch position to proceed from the stroke to the engagement point according to an e-function and thereby for the actual clutch position to cause no torque overswing. The reduction in the lower barrier n_u when understepping a boundary engine speed of 1000 1/min with no accelerator

activation, leads to an increase in the ideal torque. In order to prevent a possible stalling of the engine there is a lower engine speed of 600 1/min at which the decrementing is adjusted by n_u and the ideal torque is increased no further.

If the prediction regulator takes over the regulation as a result of a higher ideal torque then the slope is initialised to nil so long as the prediction regulator provides the higher ideal torque. Similarly also n_u is increased to its maximum when the accelerator pedal is activated, and thus the ideal friction torque of the n^2 - regulator is broken down in order to ensure a safe adoption of the prediction regulator. Furthermore in the event of an interrupted start where the "starting" is not abandoned, the n^2-regulator is initialised internally.

2. ENGAGEMENT POINT DETECTION

In the present embodiment the clutch position is measured on the transducer cylinder (GZ) in the hydraulic block and not on the receiver cylinder (NZ) on the gearbox bell (see the drawing in enclosure 1).

The temperature-dependent volume expansion of the brake fluid column between GZ and NZ falsifies the relationship of the actual clutch position (on the NZ) and the measured clutch position (on the GZ) so long as the clutch is at least partially open and thus the snifting bore in the GZ is not released.

When the clutch is closed, the system is "newly compensated" through a volume compensation through the snifting bore in the GZ.

Even after a few minutes stationary the volume change as a result of the temperature effects can cause several millimetres lift in the GZ.

When the clutch is opened the clutch position in the GZ is constantly regulated, ie when the brake fluid column warms up the piston moves in the NZ and the clutch is opened further (danger of overpressing the clutch!).

The control unit realizes nothing of this process. The next starting process would therefore be severely affected: Basically an engagement point accepted with a 0.5 mm error can already be traced subjectively in the case of all strategies (crawling, starting, re-engagement, disengagement to gear-change or stationary).

2.1 ENGAGEMENT POINT STRATEGY:

In order to have the engagement point always set as accurately as possible the following strategy is programmed into the control unit. A difference is made between a "GP-stationary", a "Gp-push" (are recorded in the background) and a current (is used for regulation) engagement point.

If the vehicle is set stationary with the engine running then there are principally two possibilities:

1. The driver has engaged the neutral gear position.
2. The driver has engaged gear and has a foot on the brake (or the handbrake is tightened) so that the vehicle does not crawl forwards.

In the first case there is the possibility of closing the clutch and thereby releasing the snifting bore so that volume compensation can take place. For this the clutch is cyclically closed for 1 second (eg every 30 seconds). On releasing the switching intent or leaving the neutral

position the process is interrupted and the clutch immediately opened. If the volume compensation has ended then the actual engagement point is set the same as the "push engagement point".

In the second case no snifting can take place. Therefore the engagement point is updated periodically (eg every 30 seconds). The clutch is thereby closed slowly (torque build-up as when crawling) until the engine speed shows a reduction of 80 1/min. The engagement point thereby detected is recorded as the "stationary engagement point". Should the engine speed not reach the required reduction then for safety reasons the detection is stopped after a certain time (of eg 1.27 seconds). This time corresponds to the calculation of an engagement point displacement of 0.5 mm and is adopted as such. This is also the maximum deviation possible fixed in the program of ± 0.5 mm between the detected "stationary engagement point" and the current engagement point (for a more detailed description see Section 2.2.1)

After detection the torque is again slowly broken down to nil (as when stopping crawling). If the clutch is again opened to engagement point + offset then the current engagement point is set the same as the "stationary engagement point".

If the driver now wants to drive or crawl forwards then the current engagement point is already adopted for this motion. If at the end of the journey or gear change the clutch is closed for a minimum of 1 second and is thus "snifted", then as above (Case 1) the " push engagement point" is adopted as the current engagement point.

The detection of the "push engagement point" is carried out

during push engagement. The condition here is that the last "snifting" must be set back a maximum time (eg 30 seconds) which however means practically no restriction since this is normally always the case. The maximum permissible change of the "push engagement point" to the current engagement point would be restricted to ± 0.2 mm.

The "push engagement point" is stored as the adaptive parameter when switching off the system and is adopted as the current engagement point when activated.

Changing over a newly detected engagement point may only take place when the clutch is either fully open or fully closed since during a coupling process a sudden change in the engagement point would cause a sudden change in the transferrable torque.

2.2 Engagement point detections

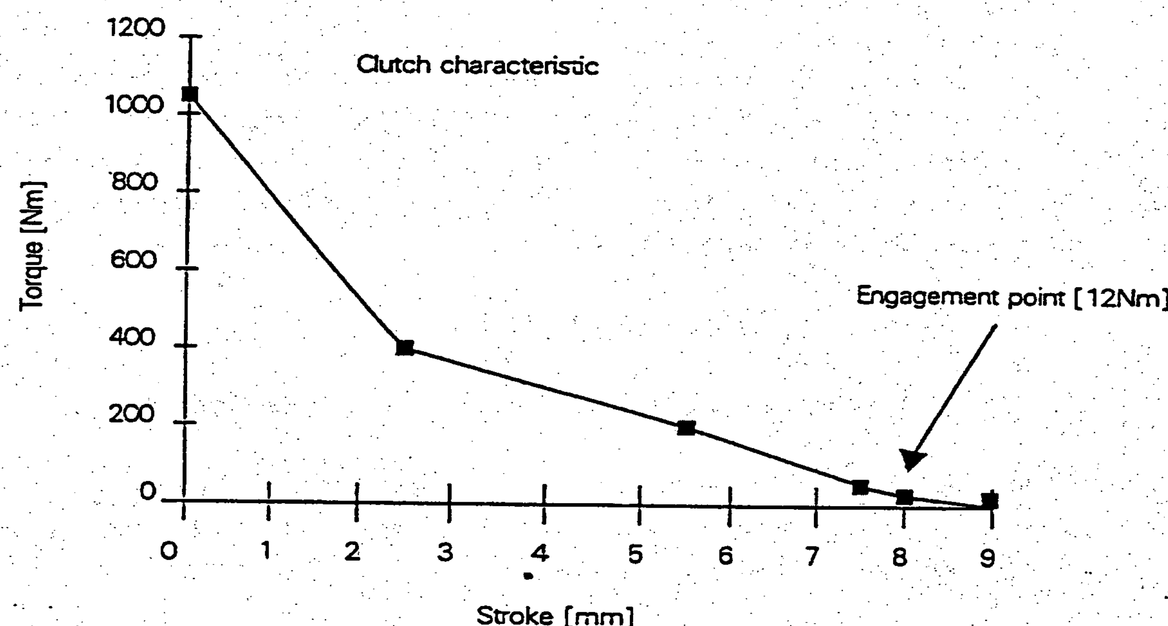
2.2.1 Engagement point detection when stationary

The engagement point detection when stationary is carried out by analysing the speed path and estimating the engagement point therefrom.

When crawling forwards, under certain starting conditions as a result of the action of the crawl regulator, the clutch always begins to close with the same relatively constant speed.

By closing the clutch the engine speed drops as soon as torque is transferred on the condition that the accelerator is not applied and the idling regulator has not yet responded. Starting from an idling speed fluctuation of ±50 1/min, with the correct engagement point and a level road

surface a speed drop of 80 1/min is always achieved within roughly the same time span. If the engagement point in the vehicle is moved to the left in comparison with the clutch characteristic line implemented in the computer (see diagram below), then this time span increases since the actor must cover a larger path from the starting position "zero point + stroke" with constant adjustment speed. When the engagement point is moved to the right then the time span is decreased.



The engagement point displacement can now be calculated from the difference between the nominal time span and the measured time span ($\Delta t-\Delta t_{nom}$) and the initial adjustment speed i_{nom},

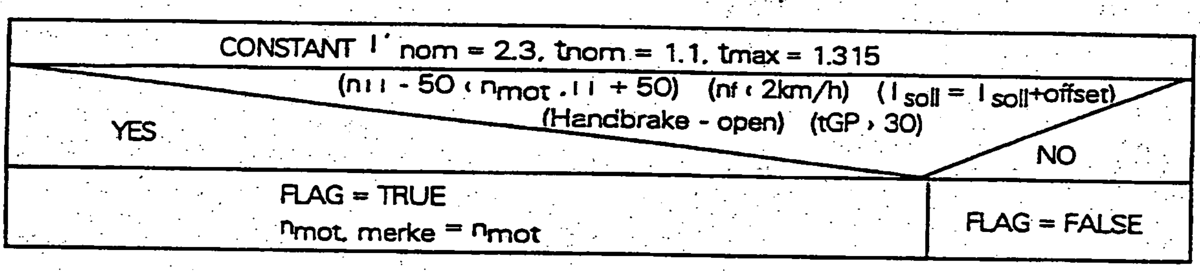
$$\Delta GP = (\Delta t-\Delta t_{nom}) \cdot i_{nom} .$$

The engagement point detection can be carried out both when the foot brake is operated and when the hand brake is operated.

Each engagement point detection can only be carried out when slipping the clutch. In order to keep the wear on the clutch to a minimum the engagement point detection when stationary is therefore only carried out every 30 seconds at maximum.

The entire algorithm which is written as its own sub-routine should constantly be called up "when driving". The initialisation for this is always called up when entering into "driving" as well as also during "driving" when the RAMPE is nil, ie crawling has not yet begun. The updated algorithm is shown in the following structogram.

Initialisation:



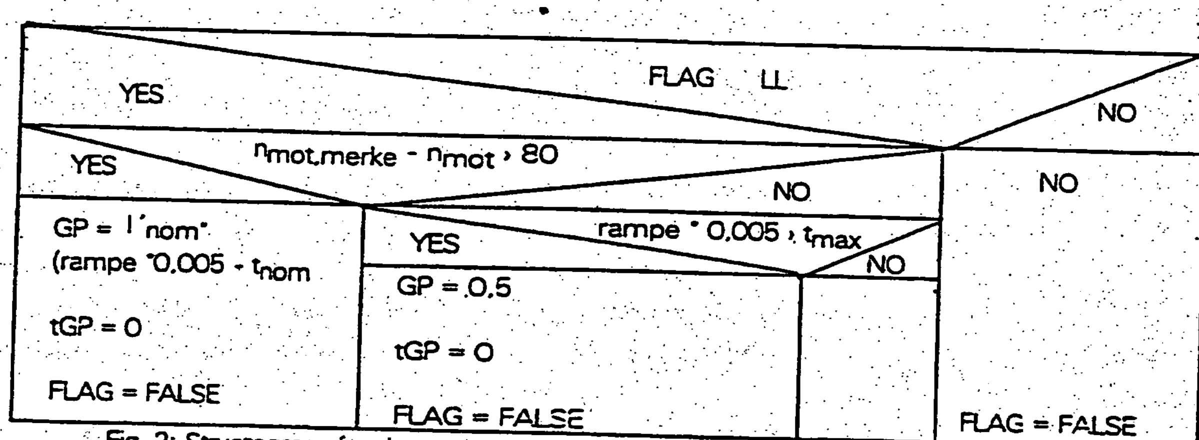


Fig. 2: Structogram for the engagement point detection when stationary

n_{mot}	engine speed
$n_{mot,merke}$	'fixed' engine speed when entering into the engagement point detection for determining the speed drop [rpm]
n_{II}	idling speed [rpm]
n_{f}	vehicle speed [km/h]
ΔGP	relative engagement point displacement (in relation to the last detected engagement point) [mm]
I'_{nom}	starting adjustment speed of clutch (nominally fixed from measured values) [mm/s]
t_{nom}	Adjustment time (nominally fixed from measured values) until engine has dropped as the crawl regulator starts to work from the idling speed to the reference point n_{mot}= 650 1/min, [s]
t_{max}	maximum time to breaking off engagement point detection, significantly owing to restriction of ΔGP to 0,5mm, [s]
tGP	Time span variable, is initialised in the event of "snifting" and at end of engagement point detection, [s]
rampe	slope from crawl regulator, serves here as time span variable
FLAG	logical variable; allows engagement point detection when the entry conditions are no longer fulfilled; is negated as soon as the engagement point detection is concluded
LL	idling switch; if TRUE then "no accelerator"

The starting conditions encountered here (engine speed approximately idling speed, vehicle practically stationary)

limit the frequency of the engagement point detection. However the nominal adjustment speed I'_{nom} can only be reached under these starting conditions with a correct engagement point (reproducibility!).

2.2.2 Push engagement point detection when re-coupling

If the engine speed after a gear change lies below the gearbox speed then the slowing engine is accelerated during the following engagement of the gearbox. This process takes place with each reverse switching with engine thrust operation and also in part during high-speed changing in the upper gears.

The basic idea of the detection now lies in transferring to the clutch at the time when the engine speed path has a minimum (stationary state, no engine acceleration), exactly that torque which corresponds to the instant drag torque of the engine (see the drawing in enclosure 2).

The drag torque can be detected from the characteristic field in dependence on the engine speed and assigned to a corresponding clutch position through the clutch characteristic line.

From this clutch position it is reset to the position in which a torque =0 is transferred.

Conversion

So that the detection can proceed logically some conditions are linked (see structogram):

the filtered slip must be constantly negative (nGetr > nMotor) up to the time when the Gp is detected;

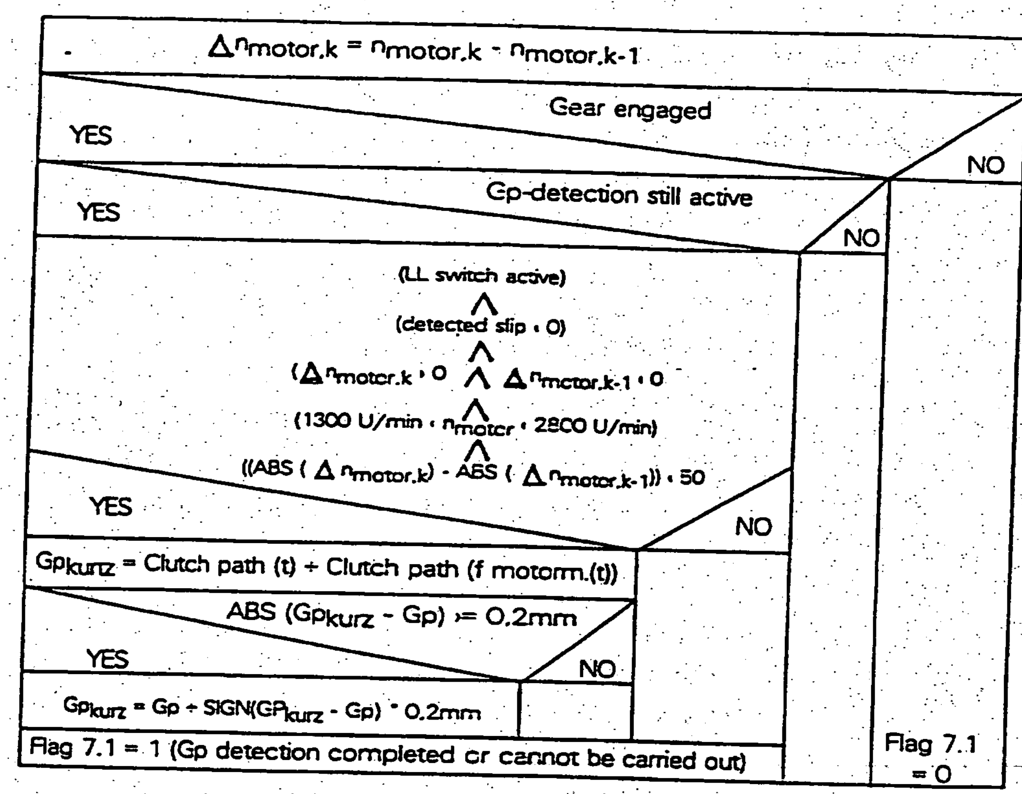
. the LL-switch must be active (DK= O*) so that the drag torque is not compensated by the engine torque;

the engine speed must not be below 1300 1/min because otherwise the idling regulator may accelerate the engine (drag torque from characteristic field then not available);

furthermore the engine speed must not exceed 2800 1/min so that the push torque is not too big (detection should take place as close as possible to the engagement point so that the characteristic line errors have less influence.);

the Gp is detected at the time when the engine gradient is passing through zero. The gradient must thereby not exceed about 83 $1/s^2$ in order to rule out faulty measurements;

the new value may differ from the detected Gp by ± 0.2 mm max.



2.2.3 Pull engagement point detection when recoupling

The pull engagement point detection when recoupling can take place for example in that the surface between the engine speed and a value reset to the gear speed is integrated over the time. If the surface exceeds a fixed maximum value then the engagement point is moved into the clutch closing direction. If the surface understeps a fixed minimum value then the engagement point is moved into the clutch opening direction.

3. SAFETY PHILOSOPHY OF HYDRAULIC ACTUATOR

3.1 System monitoring

A detailed FMEA of the ECM system was carried out. This showed that it is necessary to differentiate between 3 types of breakdown:

* Breakdown of the sensor
* Processor breakdown or breakdown of several sensors
* Breakdown of voltage supply, end steps or hydraulic supply.

The ECM system recognizes two different emergency running stages, software emergency circuit and hardware emergency circuit. The system control light shows whether an emergency running is active.

More serious faults are indicated by a rapid flashing light (flashing frequency about 4 Hz). This is the case when:

* pressure drops
* hardware emergency switching is activated, ie in the event of
  - processor failure
  - clutch position fault
  - multiple sensor error

Less serious faults are indicated by a permanent light. This applies with simple sensor faults, with the exception of the "clutch position" fault.

The warning light indicates to the driver that the functioning systems have broken down or are only operating to a restricted amount.

Table 1 illustrates the various emergency running stages with a description of the effects on the clutch control.

3.1.1 Sensor breakdown

Plausibility controls of the sensor signals are constantly taking place. If a fault is detected then a corresponding emergency program is switched on. This software emergency circuit (see Section 3.2.1) allows the basic functions to continue, ie the automatic clutch operation for driving and changing gear. However comfort restrictions must be accepted here. If several sensor faults occur at the same time then the hardware emergency circuit is activated (see Section 3.2.2).

3.1.2 Processor breakdown

The processor is monitored by an external watchdog. If as a result of a program crash the processor can no longer reset the watchdog timer then the watchdog triggers a processor reset. With a reset the clutch control is automatically switched over to a fixedly wired control circuit, the so-called hardware emergency circuit.

3.1.3 Failure of voltage supply, end steps or hydraulic power

In the event of these serious faults a system shut down takes place which causes closing of the clutch.

Case	Emergency step	Vehicle reaction	occurs when
1	'normal' ECM-control (no emergency running active)	- automated coupling when driving and during gear change - special clutch control for optimising tip-in and back-out reactions in vehicle	- no fault
2	software emergency running	- "normal" automatic clutch function when driving and during gear change with reduced comfort - Tip-in and back-out control blocked (ie clutch remains closed)	fault of one sensor (apart from clutch-path sensor error)

3	hardware emergency running.	- starter lock released - electropump time controlled for on/off switching - at engine speed < 300 1/min ==> clutch closed - at engine speeds > 400 1/min ==> clutch position dependent on throttle angle: - at small throttle valve angle, clutch is opened - at large throttle valve angle, the clutch is closed - warning light switched on	- processor failure - clutch path sensor fault - fault of several sensors
4	System shut down	- clutch closed	- voltage supply defect (cable, voltage regulator) - proportional valve end step defect - pump relay end step defect - failure of hydraulic supply.

TABLE 1: ECM Safety Philosophy

3.2 EMERGENCY CIRCUITS

3.2.1 Software emergency circuit

If at least one fault is entered in the current fault memory then the flag "SW-emergency" is set and the warning light shows <u>permanent light</u> (Exception: in the event of "pressure drop" <u>rapid flashing light</u> with about 4 Hz flashing frequency).

The operating mode " dragging" is blocked. The other measures and consequences with the various faulty conditions are listed in Table 2.

These fault measures are rescinded if the flag "SW-emergency" is cancelled. This occurs if there is no longer any current fault and the neutral gear position is engaged or the clutch is closed. Cancelling the fault measures only in the non-critical states "neutral position" or "clutch closed" prevents the switching back to the normal operation being perceptible to the driver.

The exceptions here are the faults:

* gear position

and * idling switch

which are immediately reset as soon as the relevant fault no longer exists. With these types of faults the cancellation of the replacement value in the event of the fault no longer being present is also then uncritical if the neutral position is not engaged.

Type of fault	Measures	Effects
1. Engine speed signal	* Changeover to engine secondary speed	* None
2. Gearbox input speed signal	* Replacement value $n_{Get} = 0\ min^{-1}$ * Gear recognition restricted (difference only made between 1st gear, 2nd gear and neutral	* Temperature protection measures come into effect * Driving protection for high gears out of force * Clutch opens when accelerator pedal not activated (freewheel action) * Recoupling in the train uncomfortable * Overturning protection not operative
3. Tacho speed signal	* Replacement value $n_F = 0\ min^{-1}$ * Gear recognition restricted (as 2)	* smoother coupling behaviour at high gears
4. Throttle valve signal	* Replacement value $a_{DK} = 5°$	* Starting speeds not dependent on throttle valve angle * Recoupling not adapted (either too hard or too soft depending on situation) * Rapid uncomfortable disengagement
5. Gear position transducer signal	* Replacement value set to 1st gear range * Starter block deactivated	* Softer coupling behaviour at high gears * Gearbox chatter and gearbox damage possible or provokable
6. Pressure sensor signal	* 50% switch on time - pump cycle activated	* none
7. Switching intent switch signals	* Switching intent flag = "false" set	* Increased amount of shift force to change into neutral gear position
8. Idling switch signal	* Idling switch = "false" set at DK > 5°	* Driving off poorly metered (still only crawling or driving with DK > 5° possible

TABLE 2: Measures and consequences with various fault situations in the software emergency circuit.

3.2.2 Hardware emergency circuit

The system contains a fixed-wired emergency control. In

order to maintain the system pressure the electro-pump is controlled with a fixed beat (ie 10 seconds on, 10 seconds off, 10 seconds on...). Below a minimum engine speed (stationary engine) the clutch is closed (parking lock, security against accidental rolling). When the engine is running the clutch is controlled directly through the throttle valve signal. Thus the clutch is opened with a small throttle valve angle and closes with a large throttle valve angle. The pulse width modulated signal of the throttle valve is used directly to control the valve.

The emergency control allows the car to be driven with a low risk of danger up to the next halt. Driving is however not possible in all cases since the closing process of the clutch can indeed be controlled through the accelerator pedal but the ability to meter out fuel is however very restricted.

Starting the engine is blocked when the emergency control is active. Deactivating the starter lock is only possible by plugging in a bridging plug (see Section 3.2.3).

The hardware emergency circuit becomes active when the system detects a multiple sensor fault (see Section 3.1) or the clutch position signal is destroyed or breaks down. A special operating state of the software control (Shut down) ensures the system control is transferred to the fixedly wired emergency control. The hardware emergency running is in this case not reversible and can only be lifted by switching off the control unit (ignition off, driver's door closed).

The correct functioning of the software control is monitored by a so-called "watchdog". If the processor does not send a trigger signal to the externally fitted "watchdog" circuit

at regular intervals then this circuit triggers the hardware emergency control and the processor is restarted (reset). If the processor works correctly again after renewed high speed running then the hardware emergency running is rescinded in this case.

The hardware emergency control is generally active in the high speed running phase of the software system up to about 100 ms after switching on the control unit.

On encountering the conditions:

engine speed $< 500 \text{ min}^{-1}$

and (foot brake or handbrake) operated

an engine shut-down is activated in the hardware emergency control which acts for a max. of 3 seconds. (See Section 3.3 for detailed description of this function).

If with the activated hardware emergency running the starter block bridge is plugged in and an attempt is made to start up, then if the foot or handbrake is operated, the engine shut-down comes into effect. Since however the engine shut-down only lasts for a maximum of 3 seconds the engine can nevertheless be started.

3.2.3 Deactivation of the starter blockade

The starter blockade can be circumvented by placing the bridging plug in the "starter release" socket. If the starter block bridge is pushed in then the system warning light <u>rapid flashing light</u> comes on (flashing frequency about 4 Hz). If the starter block bridge is removed again immediately after the engine starts up then the system warning light flashes until the control device switches off the next time.

3.3 DIAGNOSIS FUNCTION

The basis of self diagnosis is fault recognition.

All input and output signals are checked for faults. In the case of the input signals an omission of the physically sensible signal area leads to a fault being entered in the fault memory.

In the case of output signals the logical level is checked to agree with the re-measured level.

In addition in the case of the input signals a check is made for functional errors such as

* overlong pump switch-on times (pump cycle)
* unacceptable deviations between ideal and actual clutch position (clutch position sensor)
* comparison of engine speeds DME 1 and DME 2
* check on valve flow for physically sensible range
* check whether during a gear change the two switching intent signals are active simultaneously ==> fault "switching intent" is detected
* check on LL-switch in dependence on throttle valve
* reciprocal monitoring of gear input and tacho speed.

Each detected fault is entered in a fault memory. The fault is rated a numerical value between 1 and 8. Number 1 means the fault current exists. Higher numbers show when the fault last occurred. On switching off the system the numerical states of all the faults not currently adjacent are increased by 1 and then stored. Number level 2 thus signifies that the fault occurred during the penultimate

operating phase but is currently no longer present. A fault level between 2 and 7 is to be interpreted accordingly (eg 5: faults no longer appeared in the last 5 operating phases). Number level 8 signifies that the fault has occurred at least once since the last cancellation of the fault memory but no longer during the last 7 operating phases.

Faults which have not occurred remain unrecorded.

3.3.1 Reading the fault memory

The output of the fault memory is produced through a flashing code by means of the system warning light. In order to prepare the diagnosis output the bridging plug is set to the "diagnosis" socket. The diagnosis output begins when the ignition is switched on by operating the foot brake pedal (longer than 2.5 sec).

At the beginning of the diagnosis output a light phase flashes on for 2. 5 seconds. The flashing code output of the fault recorded in the fault memory then begins. The fault code is in three parts, the first two numbers designate the type of fault (see Table 3). The third position contains the relevant fault number. The individual number pulses are separated by a short dark phase and the individual positions through central and different fault entries by long dark phases.

After the output has run through once the warning light goes out. A new output can be triggered by operating the foot brake. During the diagnosis output the operation of the foot brake is ignored (ie no new output is started).

After pulling out the bridging plug from the "diagnosis"

socket the ignition is switched on and the fault memory cancelled.

3.4 ENGINE SHUT DOWN

During operation with extreme engagement point displacement:

when

difference zero - engagement point < 3 mm

or

difference maximum stroke - engagement point < 1mm

then switch off engine

Note: this can only happen when the vehicle is stationary for a longer time with the gear engaged.

With software emergency running:

when:

		engine speed < 500 1/min
	and	supply pressure p < 50 bar (no cable break)
	and	foot brake operated
or		supply pressure p < 50 bar (no cable break)
	and	handbrake operated
	and	flag "engine already running"
then:		switch off engine

Note: The link with the "flag "engine already running" is necessary since otherwise the engine shut down could also be active when starting the engine.

With hardware emergency running:

when

		engine speed < 500 1/min
	and	foot brake or handbrake operated
then		switch off engine

Note: if the starter were operated in the hardware emergency running (starter block bridged) then when the brake is operated the engine shut down is active. Since the signal

is accepted a maximum of 3 sec by the DME then the engine starts up with a 3 sec delay.

BACKGROUND FOR ACTIVE ENGINE SHUTDOWN WITH EXTREME ENGAGEMENT POINT DISPLACEMENT

Problem: When driving, changes in temperatures can create situations where an unintended closing of the clutch can occur as a condition of the design.

Situation 1: The vehicle is moved at high speed. The high driving speed requires a very good cooling of the hydraulic pipe. In the following the vehicle is held stationary then the hydraulic pipe heats up severely. As a result of the expansion of the brake fluid between the transducer and receiver cylinder, the transducer cylinder is moved successively in the direction of zero. Here the danger exists that in the event of particularly severe temperature increase (without driving) or when next driving off the transfer of the bore for fluid compensation ("snifting bore") in the transducer cylinder causes uncontrolled closing of the clutch.

Solution: Switch off engine as soon as the danger of an uncontrolled driving exists. Thus the clutch is closed and a fluid exchange takes place through the "snifting bore" whereby normal driving becomes possible again when restarting the engine.

Situation 2: The vehicle is brought into the disengaged state with a severely heated hydraulic pipe.

By cooling the hydraulic pipe the clutch is slowly closed. This is recognised by the engagement point adaption and moves the transducer cylinder in the clutch "opening" direction. It is now however conceivable here that the clutch path which the transducer cylinder has available is not adequate. If the transducer cylinder is at the stop the clutch is slowly closed as a result of the cool down.

Solution: Switch off engine as soon as the transducer cylinder reaches the maximum stroke. The clutch is closed and the fluid exchange through the snifting bore can take place.

The invention is not restricted to the embodiments described and illustrated but also includes those variations which can be achieved by combining individual features or elements described or illustrated in conjunction with the various embodiments and processes. The applicant reserves the right to claim as being of inventive importance further features disclosed up until now only in the description or in the drawings.

PATENT CLAIMS

1. Motor vehicle with an internal combustion engine and a gearbox and an automatic clutch mounted in the torque flow and at least one control device for the clutch, as well as with a hydraulic system with sender cylinder, receiver cylinder and a hydraulic line between sender and receiver cylinders, a hydraulic fluid and a device for volume compensation and a snifting bore, characterised in that the clutch is closed controlled at least from time to time and a volume compensation of the hydraulic fluid is carried out.

2. Motor vehicle according to one of the preceding claims, characterised in that the volume compensation is repeated, as controlled timewise, by for example taking place substantially cyclically.

3. Motor vehicle according to one of the preceding claims, characterised in that the volume compensation is carried out through at least a temporary release of the snifting bore, for example for a duration of 1 second.

4. Motor vehicle according to one of the preceding claims, characterised in that the process of volume compensation is interrupted when a switching intent is released.

5. Motor vehicle according to one of the preceding claims, characterised in that the process of volume compensation is interrupted on leaving the neutral position of the gearbox.

6. Motor vehicle according to one of the preceding claims, characterised in that the process of volume compensation is not carried out when a gear is engaged, the

brake is operated and the vehicle is substantially stationary.

7. Motor vehicle with an internal combustion engine and a gearbox and an automatic clutch mounted in the torque flow and at least one control device for the clutch, substantially as herein described with reference to the accompanying drawings.

The Patent Office

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Application No: GB 9706152.7
Claims searched: 1 to 7

Examiner: Mike Mckinney
Date of search: 18 June 1997

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Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): F2L (LB, LC, LD, LE, LK, LT).

Int Cl (Ed.6): B60K 41/22; F16D 48/02

Other: ONLINE: WPI; EDOC.

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
	NONE	

X Document indicating lack of novelty or inventive step
Y Document indicating lack of inventive step if combined with one or more other documents of same category.
& Member of the same patent family
A Document indicating technological background and/or state of the art.
P Document published on or after the declared priority date but before the filing date of this invention.
E Patent document published on or after, but with priority date earlier than, the filing date of this application.